Connecting Theory and Applications Across Complex Systems

Final Report
AFOSR GRANT FA9550-04-1-0336

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Abstract

This grant supported a workshop, held at Caltech in July 2004, that brought together experts in mathematics, physics and biology in an interactive exchange of ideas on the design, analysis, and control of complex systems. A major goal of the workshop was to bring domain experts together who normally do not interact, to explore common features of their work that can mutually reinforce and synergize theory and applications in their fields. The challenges facing experts in these domains are parallel, and their solutions are linked by common constraints. This workshop was a unique, open discussion of the threads that lead to a broader understanding of the mathematical tools necessary to tackle large problems in each area. Leaders in the areas of communications, Internet, computational complexity, biophysics, biological systems, quantum physics, statistical physics, engineering, and mathematics came together in multidisciplinary sessions, moderated and organized by other experts in these fields.

1 Accomplishments

This workshop brought together over 200 researchers in the fields of biology, mathematics, physics, engineering and other disciplines to participate in a 3 day conference exploring the the role of uncertainty and robustness in complex systems. The workshop structure can be envisioned as a 4 X 4 matrix, purposefully designed as a multidisciplinary approach, with four different application areas represented around a broad issue in complex systems (below). The four speakers in each session were organized by a moderator who challenged the group before and during the conference to highlight the common connections in the architecture and control of diverse complex systems. Each session ended with biology to highlight the recent application of diverse areas of controls to biology. The speakers are shown in Table 1.

The conference was divided into four primary sessions:

Session 1: Structure. Moderated by Hiroaki Kitano (SONY, Erato). Overall focus: Bowtie architecture, protocols, robustness and fragility, evolvability: horizontal/vertical decomposition of complex systems.

- Architecture and organization of complex systems (Richard Murray, Caltech) and medicine (Marie Csete, Emory)
- Statistical physics and HOT (Highly Optimized Tolerance) (Jean Carlson, UCSB)
- The Internet architecture (Steven Low, Caltech)

Table 1: Workshop Speaker Matrix

	Structure	**Complexity**	**Scale**	**Design**
Foundations	Murray/Csete	Parrilo	Bamieh	Dahleh
Physics	Carlson	Mabuchi	Gillespie/Petzold	Gershenfeld
Information	Low	Packard	Willinger	Paganini
Biology	Arkin	Savageau	Mitra	Khammash
(Moderators)	Kitano	Tsao	Jacobs	Glover

- Structure and function in biology (Adam Arkin, UC-Berkeley, Lawrence Livermore Labs)

Session 2: Complexity. Moderated by Anna Tsao (Algotek). Overall focus: Computational complexity, overcoming intractability, beyond simulation, tools that exploit structure to handle complexity

- Algorithmic approaches to hard problems (Pablo Parrillo, ETH Zurich)
- Quantum information and the quantum classical transition (Hideo Mabuchi, Caltech)
- Computation in complex engineering systems (Andy Packard UC-Berkeley)
- Regulation, dynamics, and complexity in biology (Michael Savageau, UC-Davis)

Session 3: Scale. Moderated by Marc Jacobs (ret., AFOSR). Overall focus: Connecting multiple physical and time scales of technological and biological systems.

- Understanding statistical and fluid mechanics (Bassam Bahmieh, UCSB)
- Multiscale and large-scale stochastic simulation (Linda Petzold, UCSB and Dan Gillespie, ret. China Lake, now Caltech/UCSB)
- Robustness and evolvability in the internet (Walter Willinger, UC-Berkeley)
- Trade-offs in neural control systems (Partha Mitra, Bell Labs/Lucent)

Session 4: Design. Moderated by Keith Glover (Cambridge). Overall focus: Distributed networks, horizontal decomposition of complex systems

- Theory of distributed control (Munther Dahleh, MIT)
- Avogadro scale engineering design (Neil Gershenfeld, MIT)
- Robust scalable Internet protocols (Fernando Paganini, UCLA and Glenn Vinnicomb, Cambridge)
- Design principles of biological networks (Mustafa Khammash, UCSB)

To enhance the educational benefits for students, an additional informal day of a tutorial introduction to the mathematics involved preceded the workshop and time was allocated at the end of the workshop for student posters to be presented.

A copy of the conference materials and attendance lists are attached to this report.

Connections, Foundations, and Edges:

Connecting Theory & Applications Across **Complex Systems**

A Celebration to Mark **John Doyle**'s 50th Birthday

July (14) 15-16 (17), 2004 / **Caltech**

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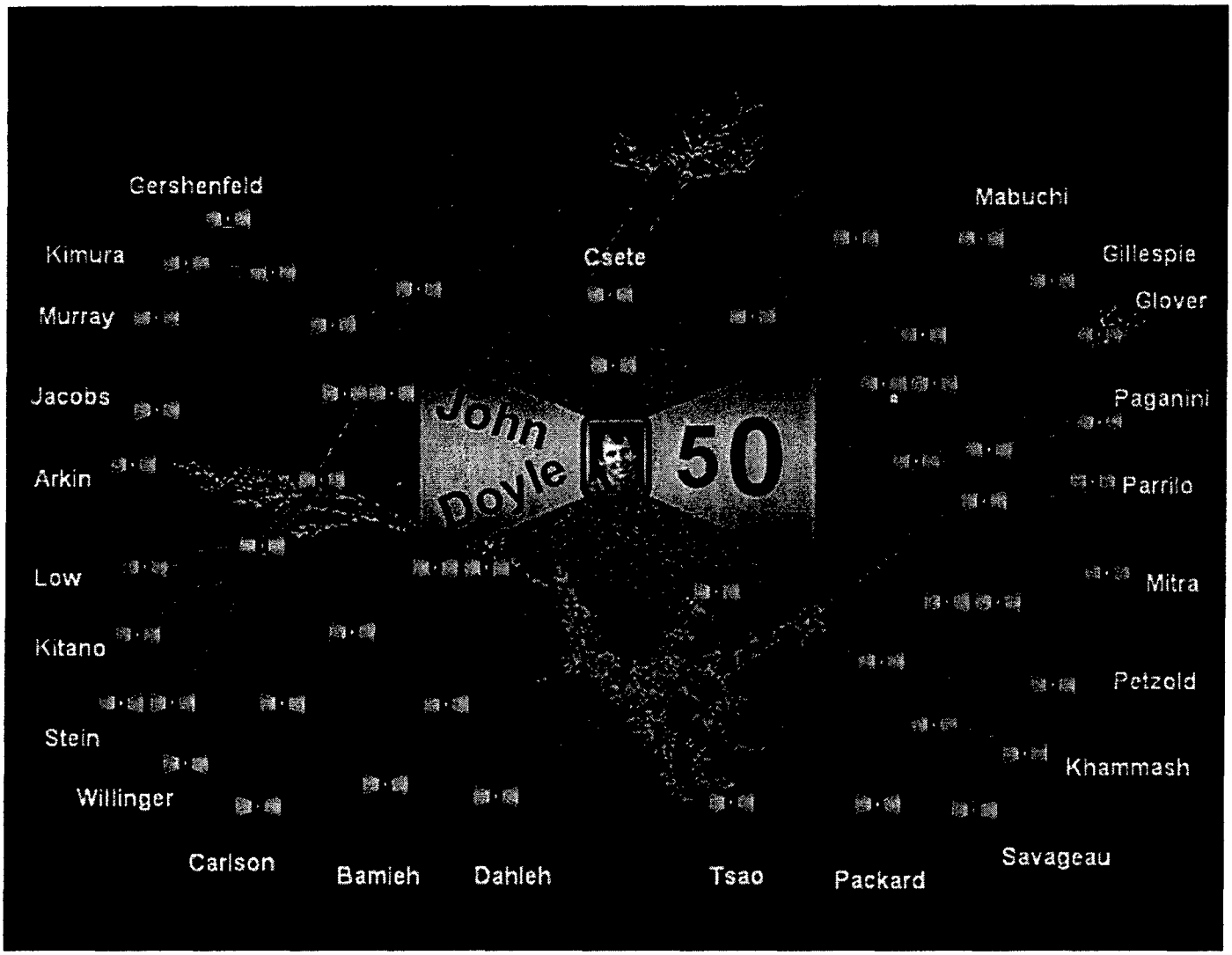

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John Doyle

Professor Doyle is the John G Braun Professor of Control and Dynamical Systems, Electrical Engineering, and Bioengineering at the California Institute of Technology. He earned his B.S. and M.S. degrees from the Massachusetts Institute of Technology, and his Ph.D. from University of California in 1984. Since then, he has done pioneering work in a broad variety of fields connected to control and dynamical systems, as well as established many athletic records in the U.S. and abroad.

Invited Talks: Thursday, Friday (July 15-16)

This symposium is designed to bring together experts in mathematics, physics, biology, and networking in an interactive exchange of ideas on the design, analysis, and control of complex systems. A major goal is to bring domain experts together who normally might not interact, to explore common features of their work that can mutually reinforce and synergize theory and applications in their fields. The challenges facing experts in these domains have striking parallels, and their solutions are linked by common constraints. This symposium will be a unique, open discussion of the threads that lead to a broader understanding of the mathematical tools necessary to tackle large problems in each area. Leaders in the areas of communications, internet, computational complexity, biophysics, biological systems, medicine, quantum physics, statistical physics, engineering, and mathematics will come together in multidisciplinary sessions, moderated and facilitated by other experts in these fields. The workshop will also produce a publication through SIAM for which the speakers will join forces with collaborators and especially with current students to elaborate on their topics in light of the workshop findings.

Background

Just 20 years ago, the 1984 ONR/Honeywell workshop on robust control helped turn a nascent and largely fringe topic into the heart of mainstream control theory. One of the most striking features of this workshop and the resulting renaissance in control theory was that the subject simultaneously became much more sophisticated mathematically, and more vigorously applied to practical applications, belying the common wisdom on the theory/practice gap. Professor Doyle's work was the explicit centerpiece of the 1984 workshop, and he actually delivered much of the first two day's tutorials, with a third day of invited talks by experts. The current workshop will focus on the invited talks, with a one-day tutorial to help create a common background, primarily intended for students. The 1984 workshop was planned for 20 people, but 120 attended, and the tutorial notes became among the most-cited references in the subject. We hope this 2004 event will have even broader impact, helping move a nascent but promising approach to a unified theory of complex systems from a fragmented discipline into the mainstream of science and

technology.There are reasons for optimism. In the last five years the traditional control and dynamical systems (CDS) community has branched out dramatically into application areas that cut across all scientific endeavors. Caltech CDS and friends have been at the front and center of this trend, already impacting areas as diverse as internet protocols, fluid mechanics, systems biology, ecology, finance, and multiscale physics. Many CDS students and collaborators have already brought novel ideas and tools from controls to areas outside their traditional training to influence these diverse fields. But it is increasingly clear that progress in the different domains would be greatly improved by dialog across disciplines, as Caltech CDS has become the hub of an ever expanding wheel of research, but one with more spokes than rim. This fragile situation would benefit from more robust connections, exactly the aim of this symposium.Engineers and biologists need to talk to each other, and to theorists who can develop a common foundation. Their communication is hampered first by language barriers with each area super-specialized in training and research. The communication requires a hard-core re-tooling, a considerable effort to which few scientists are willing and/or able to commit. If an engineer wants to inform biology, time and effort has to be put aside for learning the details and larger structure of biology, a daunting task. This workshop pulls together many people who have made that commitment at various stages in their careers, often influenced or directly motivated by their interactions with Doyle and CDS faculty, and their common language is mathematics. An underlying theme of this workshop is to look forward to ways in which future scientists can be educated in a common set of computational and quantitative methods, to prepare them to interact broadly from the time they are students and throughout their academic careers.

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Campus Map! (pdf)

Presentation files available now...
see pdf links on schedule below.

July 14 - Wednesday, 8:30 am - 5:00 pm, Winnett Center - Tutorial for Students
The symposium will be preceded by a one-day tutorial workshop organized by John Doyle primarily for students, although all are welcome to attend, to provide a common core technical background for the symposium. This will be the first attempt to present a new unified theory of complex systems and networks that builds on and integrates methods from controls, dynamical systems, information theory, computational complexity, optimization, and statistical and quantum physics. The highlight of the tutorial will be a special evening lecture by Karl Åström on "History of Controls", followed by a welcoming reception.

July 14 - Wednesday, 7:00 - 8:00 pm, Beckman Institute Auditorium - Special Speaker!
Karl Åström speaking on "History of Controls", followed by welcoming reception.

July 15 & 16 - Symposium, 8:30 - 5:00, Ramo Auditorium
The workshop structure is envisioned as a 4 **x** 4 matrix (see chart below), purposefully designed to be multidisciplinary, with four different application rows exploring a broad issue in complex systems. Each session ends with biology which of all subjects in science is the most challenging regarding organizational complexity of all sorts. At the end of each session, the four speakers in each session will be joined by a moderator to discuss with their collaborators and the audience further connections between the challenges and approaches from the different fields.

July 17 - Saturday, 9:00 - 4:00 pm, Winnett Center - Student Talks
The symposium will be followed by a very informal meeting for and by students to present and discuss their latest work on related research. All are welcome to attend, but the focus will be on student interaction.

	Thursday (15)		Friday (16)	
	Morning: **Structure** | mod (Kitano)	Afternoon: **Complexity** | mod (Tsao)	Morning: **Scale** | mod (Jacobs)	Afternoon: **Design** | mod (Glover)
	(pdf) links are to presentations			
Foundations	8:30-9:00 **Murray** (pdf) **Csete** (pdf)	1:30-2:00 **Parrilo** (pdf)	8:30-9:00 **Bamieh** (pdf)	1:30-2:00 **Dahleh** (pdf)
Information	9:00-9:30 **Low** (pdf)	2:00-2:30 **Packard** (pdf1, pdf2)	9:00-9:30 **Willinger** (pdf)	2:00-2:30 **Paganini** (pdf)
Physics	9:30-10:00 **Mabuchi** (pdf)	2:30-3:00 **Gillespie / Petzold** (pdf)	9:30-10:00 **Gershenfeld** (pdf)	2:30-3:00 **Carlson** (pdf)
breaks				
Biology	10:30-11:00 **Arkin** (pdf)	3:30-4:00 **Savageau** (pdf)	10:30-11:00 **Mitra** (pdf)	3:30-4:00 **El-Samad / Khammash** (pdf)
Panels	11:00-12:00	4:00-5:00	11:00-12:00	4:00-5:00
meals	12:00 Lunch	6:00 Cocktail Reception	12:00 Lunch	6:00 Dinner

Speaker and Contributor Biographies

Adam Arkin received his bachelor's degree from Carlton College in 1988 and his PhD in Physical Chemistry from MIT in 1992. He was a postdoctoral fellow at Stanford University from 1992-1997. In 1999, Arkin was selected by the MIT Technology Review as one of the Top 100 Most Innovative Young Scientists. He is Faculty Scientist in the Physical Biosciences Division of Lawrence Berkeley National Laboratory (since 1998), Assistant Professor of Bioengineering at the University of California, Berkeley (since 1999), and Investigator of the Howard Hughes Medical Institute (since 2000). Arkin's research is in systems and synthetic biology using quantitative measurement and modeling of regulatory network dynamics. His lab employs tools from physical chemistry, nonlinear dynamics and control theory, molecular biology, and computational biology to explore issues in bacterial and mammalian signal transduction and viral development.

Karl J. Åström was educated at The Royal Institute of Technology in Stockholm where he received an MS in 1957 and a PhD in 1960. After working for IBM Research for five years he was appointed Professor of the Chair of Automatic Control at Lund Institute of Technology where he established a new department. Åström has broad interests in automatic control including stochastic control, modeling, system identification, adaptive control, computer control and computer-aided control engineering. He has supervised 50 PhD students, written six books and more than 100 papers in archival journals. He has several patents; one on automatic tuning of PID controllers, held jointly with T. Hägglund, has led to substantial production. Åström is a member of several academies, among them the Royal Swedish Academy of Engineering Sciences (IVA) and the Royal Swedish Academy of Sciences (KVA). He is a foreign

member of the US National Academy of Engineering, the Russian Academy of Sciences, and the Hungarian Academy of Sciences. Åström has received many honors, among them five honorary doctorates, the Quazza Medal from IFAC, the IEEE Medal of Honor, and the Great Gold Medal of the Royal Swedish Academy of Engineering.

Gary J. Balas received the PhD degree in Aeronautics from the California Institute of Technology in 1990 before joining the Aerospace Engineering and Mechanics department at the University of Minnesota (UMN), Minneapolis MN USA. Professor Balas is current Director of Graduate Studies for the Aerospace Engineering and Mechanics department and Co-Director of the Control Science and Dynamical Systems center at UMN. He is a co-organizer and developer of the MUSYN Robust Control Short Course and the mu-Analysis and Synthesis Matlab and the president of MUSYN Inc. Professor Balas is a former McKnight-Land Grant Professor; this professorship is awarded to five junior faculty each year at UMN. He received the ASME Dynamic Systems and Control Outstanding Young Investigator Award in 1999 and the UMN Institute of Technology George W. Taylor Award for Distinguished Research in 2003. Professor Balas is an Associate Fellow of the AIAA and a Fellow of the IEEE.

Jean Carlson is a professor of Physics at the University of California, Santa Barbara. She is a specialist in complex systems theory, with applications in materials science, seismology, and more recently ecology and evolutionary biology. She is a recipient of a Sloan Foundation Fellowship, a Packard Foundation Fellowship, and a McDonnell Foundation 21st Century Science Award in the area of Complex Systems Theory. Currently she serves as Director of the Keck Foundation Interdisciplinary Program in Seismology and Materials Physics at UCSB, which focuses on multi-scale aspects of the earthquake problem. Recently, together with John Doyle, she introduced Highly Optimized Tolerance, a mechanism for complexity and power laws, which is based on biological evolution and engineering design. In the context of models from physics and information theory, Carlson and Doyle have illustrated how complexity may be intrinsically linked to robustness tradeoffs in systems that are highly tuned. This is the opposite of the generic, random, single tuning parameter limit which has traditionally been studied in statistical physics and complex systems theory, and HOT leads to essentially opposite fundamental characteristics and predictions from most of work in complex systems theory which has preceded it. Carlson will discuss the HOT mechanism and practical applications in a variety of areas, including the Internet and forest ecology.

Hana El-Samad is a PhD candidate at the Mechanical Engineering department of the University of California at Santa Barbara. She is expected to graduate in September, 2004. She received a Bachelor of Engineering in 1998 from the American University of Beirut, Lebanon. She also received a Master of Science in Electrical Engineering in 1999 from the Iowa State University. El-Samad's main research interests include applications of control theory and dynamical systems in physiology and molecular biology, stochastic dynamics, multiscale analysis, and noise-induced dynamical behavior in biological systems.

Neil Gershenfeld is the Director of MIT's Center for Bits and Atoms. His unique laboratory investigates the relationship between the content of information and its physical representation, from molecular quantum computers to virtuosic musical instruments. Technology from his lab has been seen and used in settings including New York's Museum of Modern Art and rural Indian villages, the White House/Smithsonian Millennium celebration and automobile safety systems, Las Vegas shows and Sami reindeer herds. He is the author of numerous technical publications, patents, and books including *When Things Start To Think*, *The Nature of Mathematical Modeling*, and *The Physics of Information Technology*, and has been featured in media such as *The New York Times*, *The Economist*, CNN, and the McNeil/Lehrer News Hour. Gershenfeld has a BA in Physics with High Honors from Swarthmore College, a PhD from Cornell University, was a Junior Fellow of the Harvard University Society of Fellows, and a member of the research staff at Bell Labs.

Dan Gillespie received his BA from Rice University in 1960, and his PhD from Johns Hopkins University in 1968. From 1968-71 he was a postdoc at the University of Maryland's Institute for Molecular Physics, where he worked in classical kinetic theory with Jan Sengers. In 1971 he became a Research Physicist in the Earth & Planetary Sciences Division of the Naval Weapons Center (now the Naval Air Warfare Center) in China Lake, California. Later

at that institution he was head of the Applied Mathematics Research Group, and finally a Senior Scientist in the Research Department. Most of his work for the Navy was aimed at developing and applying novel mathematical methods for describing, analyzing, and numerically simulating stochastic processes that arise in the physical sciences. Since his retirement from Civil Service in 2001 he has been a private consultant for the California Institute of Technology and the Molecular Sciences Institute, working mostly with Linda Petzold and her group at the University of California at Santa Barbara. His current work is aimed at developing improved methods for numerically simulating biochemical systems. He has authored or co-authored over 65 research journal articles in such diverse areas as experimental elementary particle physics, gas-phase transport theory, raindrop formation in clouds, stochastic chemical kinetics, Monte-Carlo methodology, random variable theory, vapor condensation nucleation, first-passage times, light scattering in aerosols, Brownian motion, thermal electrical noise, shot noise, foundations of stochastic process theory, and quantum mechanics. He has written three books: *A Quantum Mechanics Primer* (in print from 1970-1986), *Markov Processes: An Introduction for Physical Scientists* (Academic Press, 1992), and *Bob and Ray. And Tom*. (BearManor Media, 2004).

Marc Jacobs received his BS, MA, and PhD degrees in Mathematics from the University of Oklahoma in 1960, 1963, and 1966 respectively. During the period 1960-1961 he worked for the IBM Corporation in Endicott, NY, on a variety of topics related to what later came to be known as the "Silicon Compiler Project". From 1966-1967 he was a Research Scientist and Postdoctoral Fellow in the Center for Dynamical Systems, Division of Applied Mathematics, at Brown University. In 1967 he was appointed Assistant Professor of Applied Mathematics at Rice University, and in 1968 he returned to Brown University as an Assistant Professor in the Division of Applied Mathematics where he remained until he was appointed Associate Professor of Mathematics at the University of Missouri in 1971. In 1974 he was promoted to Professor of Mathematics at the University of Missouri, and he worked at this University until 1991. During his academic career he conducted research on a wide range of topics in optimal control theory, dynamical systems, bifurcation theory, and computational mathematics. In 1979 he was named to the Defoe Distinguished Chair in Mathematics at the University of Missouri in recognition of his research and teaching. During the period 1984-1986 he took an IPA assignment as a Program Manager in the Mathematics and Information Science Directorate of the Air Force Office of Scientific Research where he managed major programs in Dynamics and Control, Signal Processing, Applied Mathematics, and Discrete Mathematics and Operations Research. After returning to the University of Missouri in 1986 for four years, Marc decided to accept another assignment as an AFOSR IPA in 1990, and later in 1991 he accepted a permanent position at AFOSR where he managed basic research programs in Computational Mathematics, and Dynamics and Control. He retired from AFOSR in 2001 with major citations from the Air Force for the high quality of his innovative programs and the rate of his technology transitions. Specially noted were his technology transitions supporting the Airborne Laser Program, JDAM, reconfigurable and self-designing control program (RESTORE), Miniaturized Munitions Technology Program demonstrations, and the ongoing UCAV program. He is currently involved in a variety of activities as a private consultant in applied mathematics.

Hiroaki Kitano is Director of the Sony Computer Science Laboratories, Inc. and Project Director of Kitano Symbiotic Systems Project, ERATO-SORST, Japan Science and Technology Agency. He is also President of The Systems Biology Institute and an adjunct professor of Keio University. He received a BA in physics from the International Christian University, Tokyo, and a PhD in computer science from Kyoto University. Since 1988, he has been a visiting researcher at the Center for Machine Translation at Carnegie Mellon University. Kitano received The Computers and Thought Award from the International Joint Conferences on Artificial Intelligence in 1993, Prix Ars Electronica 2000, Japan Design Culture Award 2001, and Good Design Award 2001. He was an invited artist for Biennale di Venezia 2000 and Museum of Modern Art (MoMA) New York in 2001.

Steven. H. Low is Associate Professor of Electrical Engineering and Computer Science at Caltech. He received his BS in EE from Cornell University and his PhD in EE from UC Berkeley. Low was with AT&T Bell Laboratories, Murray Hill, from 1992 to 1996 and with the University of Melbourne, Australia, from 1996 to 2000. He was a co-recipient of the IEEE William R. Bennett Prize Paper Award in 1997 and the 1996 R&D 100 Award. He is on the editorial boards of IEEE/ACM Transactions on Networking, Computer Networks Journal, and is a Senior Editor of

IEEE Journal on Selected Areas in Communications. His research interests are in the control and optimization of networks and protocols.

Hideo Mabuchi has worked in optical and atomic physics, using a combination of experimental and theoretical approaches. His continuing research focuses on the use of real-time feedback for active control of quantum systems, non-equilibrium dynamics of bio-molecular systems, and quantum information science. Mabuchi is currently an Associate Professor of Physics and Control and Dynamical Systems at the California Institute of Technology; he received his AB from Princeton University and PhD from Caltech. Selected honors include an A. P. Sloan Research Fellowship and a John D. and Catherine T. MacArthur Foundation Fellowship.

Partha Mitra is currently professor of Neuroscience at the Cold Spring Harbor Laboratory (2003-present). He obtained his BSc from Presidency College, Calcutta, and a PhD in theoretical Physics from Harvard University in 1993. From 1993-1995 and 1995-2003 he was at Bell Laboratories, first as a postdoctoral researcher and then as a Member of the Technical Staff in the theoretical physics group. He spent most of 1996 at Caltech as an assistant professor in theoretical physics and built up collaborations with Caltech researchers including John Doyle. At Bell, his research interests shifted from theoretical physics to biology, mainly neuroscience. Having realised that theoretical engineering principles were critical to understanding biological systems, he worked on a number of communication theory problems at Bell. This work included determination of nonlinear limits to the information capacity of optical fiber, and the joint invention of triply polarised wireless communications to take advantage of increased wireless capacity in a scattering medium. His current work includes neuroinformatics, and the study of design principles in biological systems.

Richard Murray is Professor of Mechanical Engineering and Chair of the Division of Engineering and Applied Science at Caltech. Murray's research is in the application of feedback and control to mechanical, information, and biological systems. Current projects include integration of control, communications, and computer science in multi-agent systems, information dynamics in networked feedback systems, analysis of insect flight control systems, and synthetic biology using genetically encoded finite-state machines. Murray is currently developing a new course at Caltech that is aimed at teaching the principles and tools of control to a broader audience of scientists and engineers, with particular emphasis on applications in biology and computer science.

Fernando Paganini received his Ingeniero Electricista and Licenciado en Matematica degrees from the Universidad de la Republica, Montevideo, Uruguay, in 1990, and his MS and PhD degrees in Electrical Engineering from Caltech, in 1992 and 1996 respectively, under the direction of John Doyle. From 1996 to 1997 he was a postdoctoral associate at MIT. Since 1997 he has been with the Electrical Engineering Department at UCLA, where he is currently Associate Professor. His research interests are robust control, distributed control, and networks. Paganini is a recipient of the O. Hugo Schuck Award for best paper in the 1994 American Control Conference, the Wilts and Clauser Prizes for his PhD Thesis at Caltech in 1996, the 1999 NSF CAREER Award and the 1999 Packard Fellowship.

Linda Petzold is currently Professor in the Department of Mechanical and Environmental Engineering, and Professor and Chair in the Department of Computer Science, at the University of California Santa Barbara. She received her PhD in Computer Science in 1978 from the University of Illinois. From 1978-1985 she was a member of the Applied Mathematics Group at Sandia National Laboratories in Livermore, California, from 1985-1991 she was Group Leader of the Numerical Mathematics Group at Lawrence Livermore National Laboratory, and from 1991-1997 she was Professor in the Department of Computer Science at the University of Minnesota. Petzold was elected to the National Academy of Engineering in 2004. She was awarded the Wilkinson Prize for Numerical Software in 1991, the Dahlquist Prize for numerical solution of differential equations, in 1999, and the AWM/SIAM Sonia Kovalevsky lecturer in 2003.

Michael Savageau received an interdisciplinary PhD in cell physiology and systems science from Stanford University in 1967 and, after postdoctoral work at UCLA and Stanford,

joined the University of Michigan faculty in 1970. He was Chair of the Department of Microbiology and Immunology from 1992-2002. He was named the Nicolas Rashevsky Distinguished University Professor in 2002. In 2003 he moved to the University of California, Davis, where he is currently Distinguished Professor of Biomedical Engineering and Member of the Microbiology Graduate Group. The focus of Savageau's research is on quantitative systems biology aimed at the elucidation of biological design, with particular emphasis on the function, design and evolution of gene circuitry. He has developed generic methods for mathematical and computer representation of complex biochemical systems, and for rigorous comparison of alternative designs.

Anna Tsao received her BA (1972) and MS (1974) in mathematics from Michigan State University and her PhD degree in mathematics from the University of Michigan (1981). She has held academic positions at the US Naval Academy (1980-83) and Texas Tech University (1983-84), and industrial positions at Hughes Aircraft Company (1984-86), AT&T Bell Labs (1986-88), and the Center for Computing Sciences of the Institute for Defense Analyses (1988-1999). From 1994 to 1998, she was a program manager for Applied and Computational Mathematics at the Defense Advanced Research Projects Agency (DARPA). While at DARPA, she conceived and obtained DARPA funding for four major multidisciplinary thrusts: Physically Based Signal/Image Processing, Virtual Integrated Prototyping (VIP) for Vapor Deposition of Functional Thin Films, Optimized Portable Application Libraries (OPAL), and Virtual Electromagnetic Testrange (VET). Research she funded, managed, and championed has resulted in broad technological and industrial impact within both the Department of Defense and commercial arenas in areas that include data compression, automatic target recognition, computational electromagnetics, computer science, and microelectronics/materials processing. She is President and co-founder of AlgoTek, Inc., whose mission is to enable quantum leaps in technology through intellectual property development at the interface of mathematics, computer science, science, medicine, and engineering. AlgoTek specializes in the conception and execution of R&D visions that result in breakthrough information processing technologies for defense and industrial applications. She has published in mathematics and computer science, served as a scientific advisor to several commercial companies, is a member of the Board of Trustees and Committee on Science Policy of the Society for Industrial and Applied Mathematics (SIAM), and serves on the editorial board for the SIAM Frontiers in Applied Mathematics book series.

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This grant supported a workshop, held at Caltech in July 2004, that brought together experts in mathematics, physics and biology in an interactive exchange of ideas on the design, analysis, and control of complex systems. A major goal of the workshop was to bring domain experts together who normally do not interact, to explore common features of their work tha can mutually reinforce and synergize theory and applications in their fields. The challenges facing experts in these domains are parallel, and their solutions are linked by common constraints. This workshop was a unique, open discussion of the threads that lead to a broader understanding of the mathematical tools necessary to tackle large problems in each area of communications, Internet, computational complexity, biophysics, biological systems, quantum physics, sessions, moderated and organized by other experts in these fields.

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